BEHAVIOR OF TWO EAST COAST STORMS, MARCH 13–24, 1958

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1. INTRODUCTION

During the period March 13–24, 1958, two major storms moved northeastward along the Atlantic coast with very similar evolution and development. Although both storms decelerated near New England, their subsequent behavior was quite different. The earlier storm weakened as a secondary Low to its east intensified and moved into the central Atlantic Ocean. The following storm maintained its intensity after becoming stationary, and the weak secondary which formed to its east moved rapidly into the Atlantic Ocean. The weather associated with these two storms was typical of east coast developing Lows, with heavy precipitation and snow accumulations causing severe economic losses as transportation, power, and telephone services were disrupted. Other *Monthly Weather Review* articles [2, 5, 14] have dealt with various aspects of the formation and deepening of east coast Lows; the authors will investigate here some of the causes for the differences in the post-development behavior of these two storms. The charts shown in the illustrations are the operational ones used in the National Weather Analysis Center.

2. SURFACE DEVELOPMENTS

Two instances of surface cyclogenesis, classified by Elliot as "Gb" [3] and by Miller as "B" [9], occurred off the Carolina coast during the middle of March. The surface pressure patterns at the time of cyclogenesis (fig. 1a, 1200 GMT, March 13, and fig. 1d, 1200 GMT, March 18) showed remarkable similarity. In both cases, a ridge from a high pressure center in central Canada extended southward through the Central Plains to Texas with another ridge extending southeastward over New York and New England. In each case, a trough oriented in the east-west direction prevailed in the Atlantic Ocean south of Newfoundland. The storm of March 13–17, identified henceforth as "Storm A," had its origin in a wave of small amplitude which formed on the polar front in the Gulf of Mexico and had moved northeastward to a position north of Birmingham, Ala., at the time of cyclogenesis. (The surface fronts over Alabama were not drawn into the area of lowest pressure because of the strong thermal gradient through the closed low center.) The storm of March 18–22, "Storm B," began as a frontal wave which moved eastward from Texas to a position over Georgia where cyclogenesis occurred. In each case, the cyclogenesis resulted in a dominant cyclonic circulation which moved northeastward along the Atlantic coast, as the original low center filled over the southern Appalachians.

The direction of motion, speed, and intensification of the two storms during the 48-hour intervals after cyclogenesis were investigated to reveal any anomalous behavior. Storm A moved northeastward at 20 knots, declerated to a forward speed of 10 knots east of Nantucket, Mass., and deepened to a minimum central pressure of 980 mb. (fig. 1b). Storm B moved northeastward more slowly at 10–12 knots, decelerated south of Long Island, N. Y., and deepened to a central value of 980 mb. (fig. 1e). The paths of both storms approximated the normal tracks listed by Klein [8] and by Bowie and Weightman [1] for Texas and East Gulf type Lows. The track and degree of deepening of both storms were satisfactorily indicated by computations for Category IV Lows following the method of George [6], although the computed track of Storm B was farther east than the observed track. The speed of Storm A agreed well with the Bowie and Weightman average speed and with the computed speed; however, the speed of Storm B (10–12 knots) was slower than the average and also less than that indicated by the George computations. Neither the average speed nor the computed speed gave an indication of the deceleration south of the blocking High aloft over eastern Canada.

The surface patterns after the two storms reached full intensity (fig.1 b and e) again showed marked similarity. In both instances a high pressure ridge persisted from central Canada southward to Texas with another ridge extending southeastward toward the Maritime Provinces. One might have expected from surface considerations alone that, after becoming full-fledged "Northeasters," the storms would show similar behavior during the following 24 hours. However, the actual developments (fig. 1c and f) during that time were not the same. The circulation around Storm A weakened and the central pressure rose to 993 mb. as a more intense secondary center of 988 mb. developed to its east. Storm B decelerated and became stationary but maintained the same intensity (988 mb.) while a relatively weak secondary center (998 mb.) developed to the east.

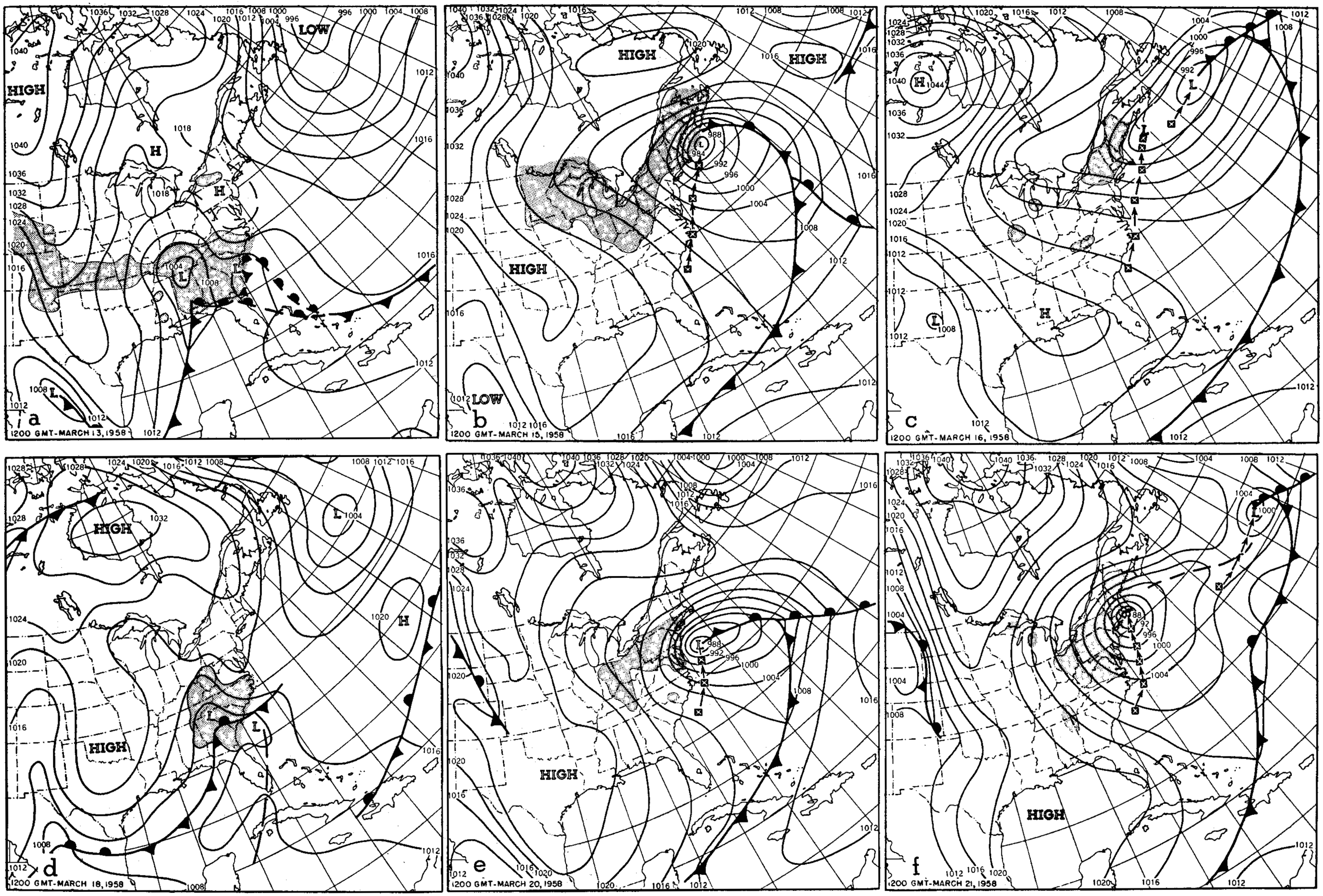

FIGURE 1.—Sea level charts for Storms A (a, b, c) and B (d, e, f). Shaded areas indicate current precipitation. Storm positions are shown at 12-hour intervals. The three maps for each storm show cyclogenesis off the east coast (a, d), maturity (b, e), ard development of the secondaries (c, f).

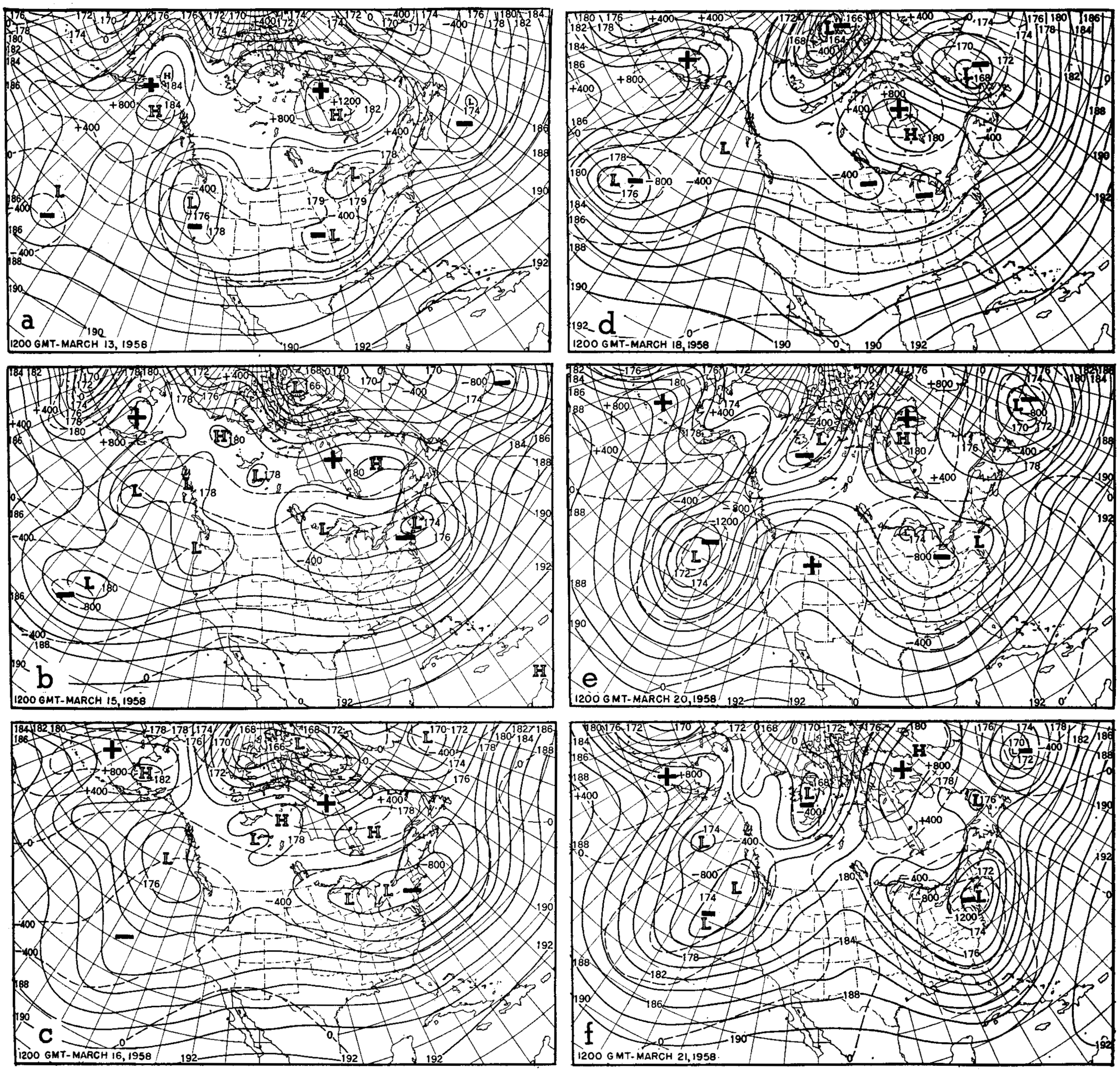

FIGURE 2.—500-mb. contours (solid lines) and their departure from normal (dashed lines) labeled in hundreds of feet. Maps are for same times as those of figure 1.

3. PRECIPITATION PATTERNS

At 0600 GMT March 13, precipitation associated with Storm A began along the Georgia-South Carolina coast and, in the following 52 hours, had occurred all along the east coast of the United States north of Georgia. As the primary Low off the New England coast began to fill, precipitation in decreasing amounts continued to fall until March 18 when only scattered showers over New England remained. This storm left a 1-inch area of precipitation from Vermont southward to New Jersey, and a small 2-inch accumulation around Boston, Mass. The "storm yielded 3 to 8 inches of snow generally over Connecticut and Rhode Island, with 10 to 20 inches over northwestern Connecticut. Three to 5 inches [snow] accumulated over coastal Massachusetts where rain accounted for much of precipitation totals: and up to 12 inches elsewhere in Massachusetts and southern and central portions of northern New England". [12]

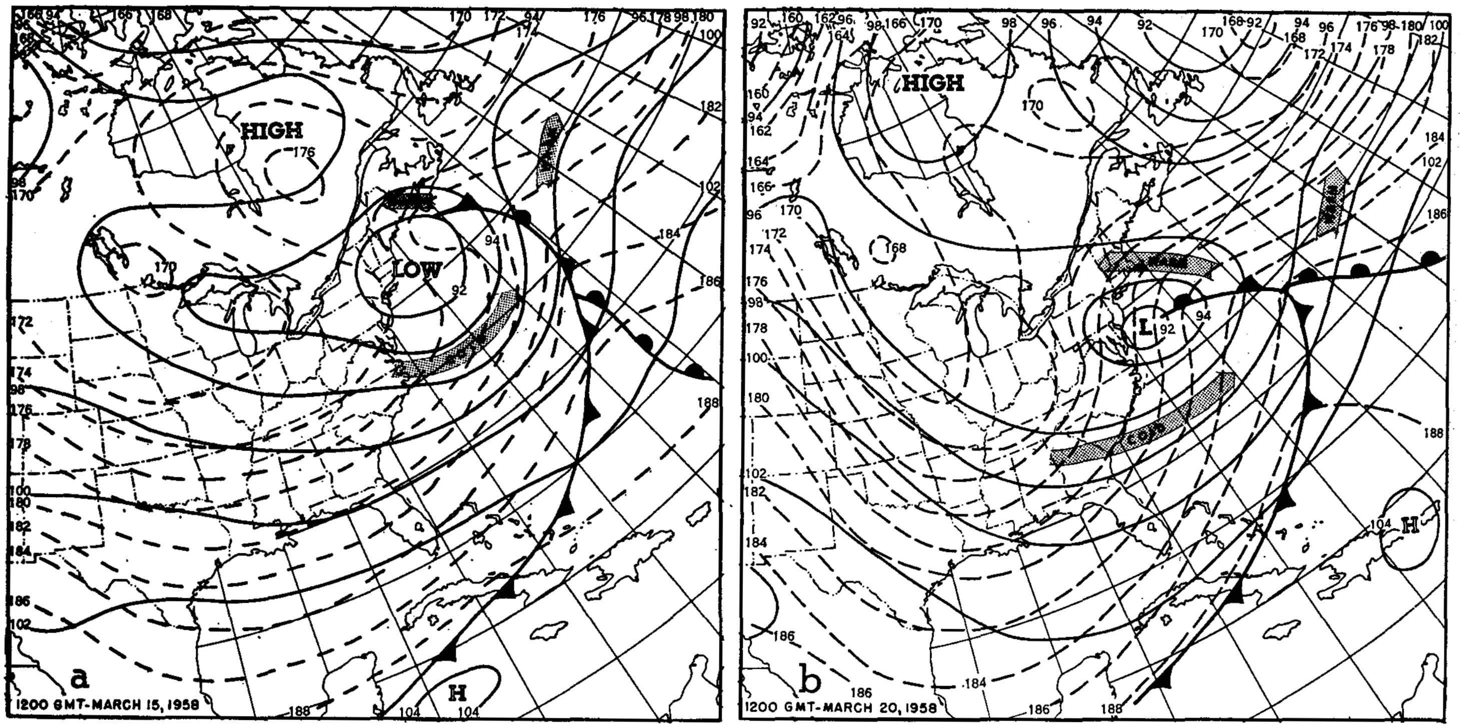

FIGURE 3.—700-mb. contours (solid lines) with superimposed surface fronts and 1000–500-mb. thickness contours (dashed lines) for (a) 1200 GMT, March 15 and (b) 1200 GMT, March 20. Arrows indicate areas of significant advection.

The precipitation area of Storm B spread more slowly up the east coast, reaching only as far as southern New York and Connecticut in the 52-hour period after the initial appearance of rain along the Georgia-Carolina coast (1200 GMT, March 20). This storm resulted in over 2 inches of precipitation in large areas of New Jersey, Delaware, and parts of the surrounding States. Much of this precipitation fell as paralyzing quantities of snow, and the storm was described as "the worst in 40 years in Pennsylvania" [13]. This description applied to many other sections as well. Counties in southeastern Pennsylvania measured 30 to 40 inches of snow; Mount Airy, Md., 29 inches; and Westminster, Md., 27 inches. The precipitation then proceeded slowly into New England, in smaller amounts however than those associated with Storm A. By March 23, only scattered showers over New England remained from Storm B.

4. ANALYSIS OF POST-DEVELOPMENT BEHAVIOR

The behavior of the secondary developments associated with these two storms illustrates an important problem facing the forecaster: namely, whether the primary Low will fill as an intense secondary forms, or whether the primary Low will maintain its intensity as only a weak secondary develops.

One convenient technique for differentiating between secondary developments is given by Sawyer [10], who states that, with slowly-moving Lows, secondary developments at the point of occlusion can be divided into two types. One type is characterized by secondary development at the warm air crest of a cold-type occlusion and by a forward motion of 10–12 knots, often with temporary rapid deepening; the other type, by development at the warm air crest of a warm-type occlusion, followed by "breaking away" of the secondary at speeds of 30–50 knots, with weakening central pressures.

The thickness pattern [1] associated with Storm A (fig. 3a) met Sawyer's criteria for the cold-type occlusion. The thermal gradient over the primary Low was very weak. The cold-advection arrow indicated the more intense thickness gradient behind the occlusion, with difluence (fanning out) of the thickness lines ahead of the point of occlusion. An intense secondary development did take place by 1200 GMT, March 16 (fig. 1c) and moved eastward at a speed of 25 knots, maintaining a central pressure of 988 mb. as the primary Low filled. This speed was somewhat greater than that indicated by Sawyer and no further deepening of the secondary occurred. The thickness pattern associated with Storm B (fig. 3b) not only differed from that which occurred with Storm A, but also met Sawyer's criteria for the warm-type occlusion. The stronger thickness gradient was located to the east of the primary Low with the confluence of the thickness lines ahead of the point of occlusion. A secondary development (central pressure 998 mb.) did take place by 1200 GMT, March 21 (fig. 1f), and the secondary filled as it

[1] Used operationally in the National Weather Analysis Center as an "advection chart" (1000–500-mb. thickness lines superimposed on the 700-mb. contours) with the assumption that the 700-mb. flow represents the mean flow in the 1000–500-mb. layer in the manner of Sutcliffe [11].

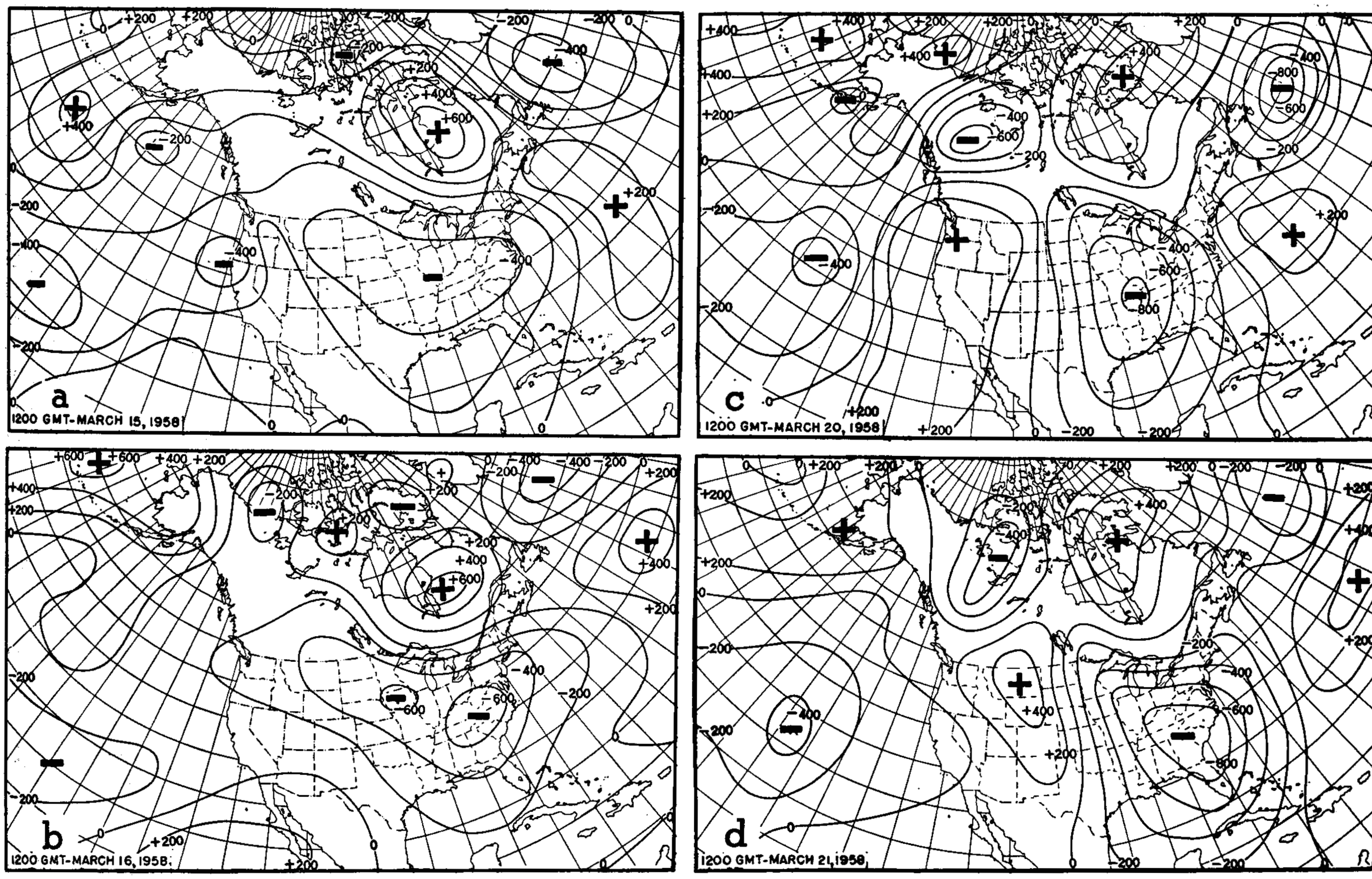

FIGURE 4.—Departure from normal of the 1000–500-mb. thickness during Storm A (a and b) and Storm B (c and d).

moved eastward at a speed of 45 knots in agreement with Sawyer's rule for this type.

Further examination of the thickness patterns associated with the primary Lows revealed other significant differences. Little warm advection remained over Nova Scotia and Maine, associated with Storm A (fig. 3a), while more intense warm advection is indicated by the arrow south of Newfoundland. The maximum cold advection was located off the east coast to the south of the surface Low. There was little additional cold air advection into the surface storm as the thickness gradient weakened inland over the Appalachians. Since only relatively weak thermal advection remained over Storm A at this time, no further deepening would be expected, and presumably filling of the Low center would occur as development associated with the maximum cold and warm advection took place farther east. On the other hand, the maximum cold air advection associated with Storm B (fig. 3b) occurred southwest of the surface Low with an intense thickness gradient westward over the Appalachians. This pattern indicated continued cold advection into the surface storm, which, coupled with the maximum warm advection over New England, maintained the cyclonic circulation around Storm B. Only weak warm advection was indicated in advance of the point of occlusion.

The upper-level height patterns associated with the respective life cycles of the storms were also investigated to account for the different secondary developments at the surface. The 500-mb. patterns for Storm A (fig. 2 a, b, c) and Storm B (fig. 2d, e, f) were selected for the same times as the surface charts in figure 1 to illustrate the stages of cyclogenesis, maturity, and secondary development. For further definition of the patterns, the departures from normal of the 500-mb. heights have been superimposed on the contours.

The upper-level pattern over eastern North America during the period March 13–24, 1958, was dominated by a High and a ridge over eastern Canada, with low centers in the central North Atlantic and over the Great Lakes. Since this blocking pattern existed throughout the history of both storms it could not account for the different behavior after maturity; accordingly, the 500-mb. features upstream were examined.

Elsewhere the upper-level patterns associated with Storms A and B at the time of cyclogenesis (fig. 2 a and d) showed some similarity. The 500-mb. flow at 1200 GMT, March 13 would be classified as "zonal," with an east-west-oriented negative anomaly pattern across the central United States and the same alignment of the positive anomalies from eastern Canada to Alaska. The southern branch of the westerlies was depressed along the southern United States border with little or no flow over the area from the Great Lakes westward to Oregon. The shortwave trough associated with the surface cyclogenesis was located over Louisiana in the fast westerly band. The corresponding 500-mb. pattern occurring with Storm B had similar zonal characteristics, although the broad band of the westerlies had shifted northward with practically no anomaly gradient over the United States. The shortwave trough associated with the surface cyclogenesis was poorly defined in the broad cyclonic circulation over the central United States. The main difference in the upstream pattern occurred along the Oregon coast, where a ridge was now located in contrast to the closed low circulation over this area at the time of inception of Storm A.

Forty-eight hours later, during the mature stage of the storms just prior to the secondary development, the differences between the two 500-mb. patterns had become even more significant. The upper flow associated with Storm A (fig. 2b) was still zonal in character with little amplitude of the westerlies as the 500-mb. jet remained at low latitudes. By 1200 GMT, March 15, the upper Low and the associated major trough, intensifying in response to the baroclinic deepening of the surface storm, had progressed eastward from Missouri to a position near Long Island, N. Y., where it was located almost directly over the surface Low. The long-wave trough as indicated by the Fjørtoft [4] space-mean chart was located along the east coast. The corresponding 500-mb. pattern for Storm B (fig. 2e) had become more meridional in character, with increased amplitude of the ridge over the western United States as the long-wave trough at middle latitudes retrograded from the Oregon coast (Storm A) to the eastern Pacific (see article by Green in this issue [7]). The long-wave trough located earlier along the east coast also shifted westward and was in a position west of the Appalachians at 1200 GMT, March 20. The 500-mb. jet now entered North America along the Canadian border and the strong northwesterly winds over the Central Plains maintained the increased amplitude of the major trough associated with the upper Low over the Great Lakes. A separate low center aloft in the shortwave trough associated with Storm B was forming over Maryland as the major trough remained west of the Appalachians.

Further magnification of the differences between the characteristic zonal and meridional patterns may readily be found in a comparison of the anomaly fields. It was pointed out earlier that the upper flow remained zonal throughout the cycle of Storm A (fig. 2 a, b, c).

The axis of the negative anomaly pattern which covered practically the entire United States was oriented east-west, with little gradient. By the time Storm B matured (fig. 2e), the flow had become meridional, as indicated by the north-south orientation of the negative anomalies off the west coast and over the Mississippi Valley as well as by the positive anomaly center over the Rockies. The departures from normal of the 1000–500-mb. thickness (fig. 4 a and c) depict even more markedly the zonal and meridional characteristics of the upstream patterns. For Storm B the gradient of the thickness departures from normal was in excess of 1000 feet between the Mississippi Valley and the west coast, compared with less than 300 feet over the same area for Storm A. After the secondaries formed 24 hours later, the gradient of the thickness departures from normal upstream from Storm B (fig. 4d) increased to more than 1,200 feet between the east coast and the Rockies, while in the case of Storm A the gradient showed little change.

Figure 2 b and e clearly reveal the difference in the positions of the major troughs at 500 mb. when the secondary developments occurred. In the first case, the Low aloft was almost directly over the surface storm, and the major trough lay off the east coast near the surface cold front. Thus the secondary, developing at the point of occlusion, had associated with it a favorable upper-air flow and could be expected to maintain its intensity. In the case of Storm B, a short-wave trough was associated with the surface cold front, the major trough lying west of the Appalachians. This meant that the primary Low could remain near the east coast as the major trough progressed eastward, but that any secondary development would occur in the relatively major ridge with an upper flow pattern unfavorable for intensification.

The 500-mb. patterns for the times following the secondary developments are shown in figure 2 c and f. The flow associated with Storm A maintained its zonal character, with the upper trough continuing eastward south of Nova Scotia together with the secondary Low. In the case of Storm B, the upper flow maintained its meridional character at middle latitudes as the major trough moved to the east coast; there was little definition of the short-wave trough as it moved through the ridge position along the longitude of Newfoundland.

5. CONCLUSIONS

The behavior of two typical east coast "Northeasters" has been discussed. The post-development behavior of the storms differed as subsequent secondary "breakoff" Lows formed. Some of the pertinent aspects of the associated synoptic patterns that led to each type of secondary Low are as follows:

Surface: No major differences in the surface patterns associated with Storms A and B could be found.

Upper Levels:

1. The 1000–500-mb. thickness gradients indicated a cold-type occlusion in Storm A and a warm-type occlusion in Storm B.
2. Orientation of the thickness gradients around the primary Lows indicated little thermal advection

Upper Levels—Continued

associated with Storm A and continued strong thermal advection around Storm B.

3. The location of the major troughs relative to the mature surface storms indicated whether the upper-air flow was favorable or unfavorable for the secondary developments.
4. The upstream departures from normal of both the 500-mb. heights and the 1000–500-mb. thickness showed characteristics which were zonal in the case of Storm A and markedly meridional in the case of Storm B.

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